The 2009 Europhysics Conference on High Energy Physics
Krakow, July 16th - 22nd, 2009

Charmed Mesons in Deep Inelastic Scattering at HERA

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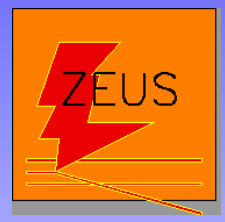
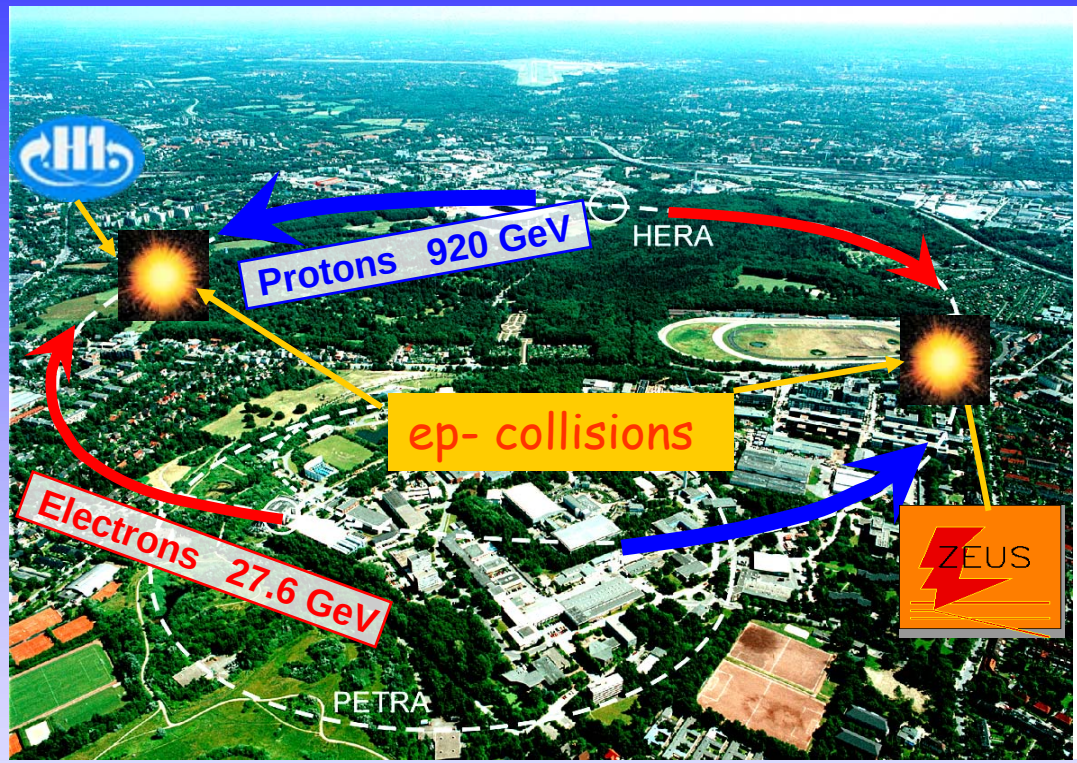
on behalf of the
H1 and ZEUS collaborations

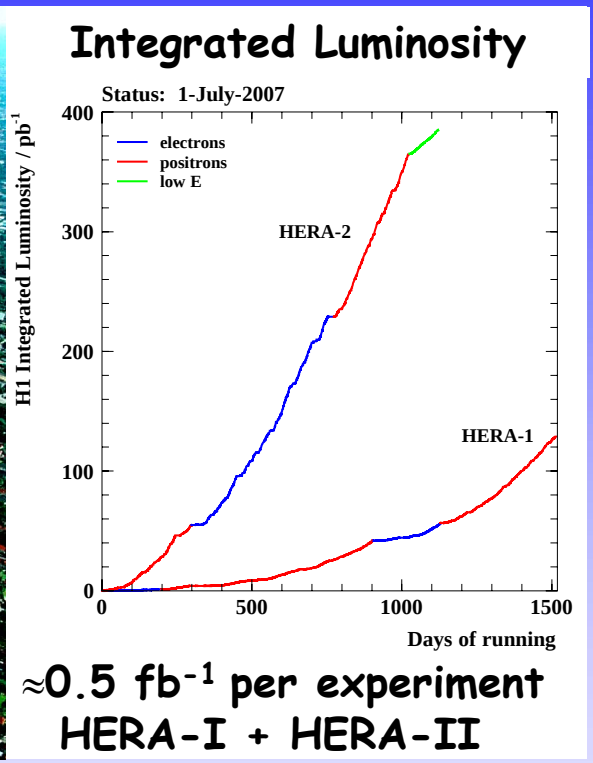


Outline:

- **HERA & kinematics at HERA**
- **Theory of open charm production in ep-scattering**
- **Inclusive cross sections of D meson production**
- **Charm contribution F_2^c to the proton structure function**
- **Conclusions**

The HERA accelerator





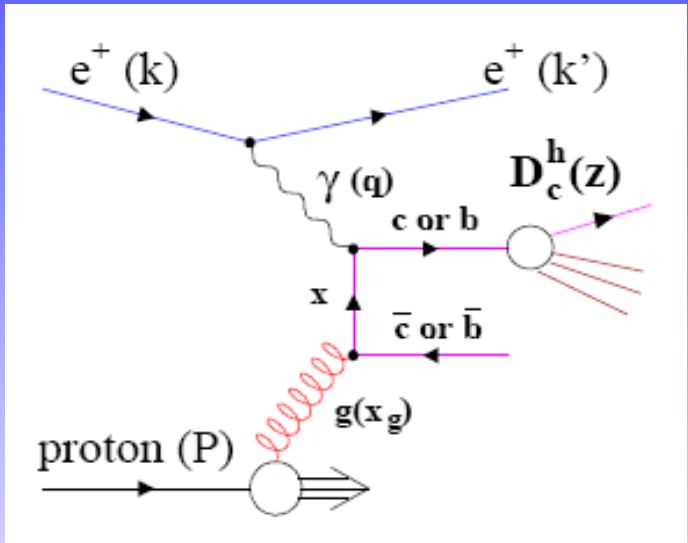
≈0.5 fb^{-1} per experiment
HERA-I + HERA-II

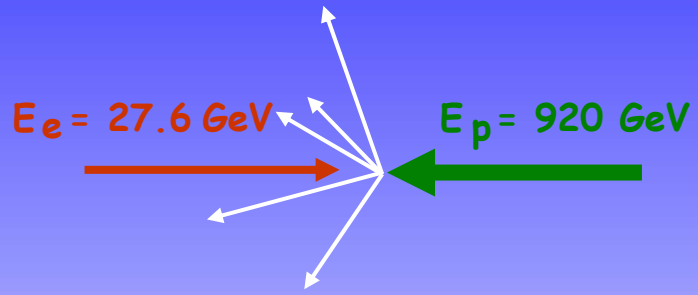
$\sqrt{s}$ = 318 GeV

This talk: Results from HERA-II running only

Open Charm Production in DIS

Predominantly: **Boson-Gluon-Fusion (BGF)**





ep-Kinematics:

$\sqrt{s}$ = 318 GeV (energy c.m.)

$Q^2=-q^2$ (photon virtuality)

$x=x_{BJ}$ (fraction of proton momentum carried by the struck quark)

2 kinematic regimes :
$Q^2 \cong 0$ GeV^2 : **Photoproduction (γp)**
$Q^2 > 1$ GeV^2 : **Electroproduction (DIS)**

Factorisation:

$$\sigma^h = \text{PDF} \otimes \text{M.E.} \otimes \text{FF}$$

Theory approaches for charm production

Massive fixed order QCD calculation, FFNS

- heavy flavours generated dynamically via BGF
- correct threshold treatment
- valid for $\mu^2 \approx \mathcal{O}(m_c^2)$
- expected to fail at some scale $\mu^2 >> m_c^2$

Model for charm production in DIS and inclusive charm meson production available : HVQDIS

Massless calculation (ZM-VFNS)

- massless charm as part of the proton
- not valid at threshold
- expected to work at HERA at large p_t

will be compared to data

Generalized mass calculation (GM-VFNS)

- massive at $\mu^2 \approx m_c^2$ and massless at $\mu^2 \gg m_c^2$
  - no predictions for the final state in DIS (F_2^{cc} only)

Monte Carlo event generators

RAPGAP

- collinear partons in the proton
- massive matrix element calculated in LO QCD
- higher order contributions via parton showers
- parton evolution based on DGLAP equations

CASCADE

- only gluons in the proton
- un-integrated gluon density (k_T)
- massive off-shell matrix element
- initial state parton showers to all orders based on CCFM equations (P_{gg} only)
- final state parton showers à la Jetset

Hadronization via Lund String model (Jetset)

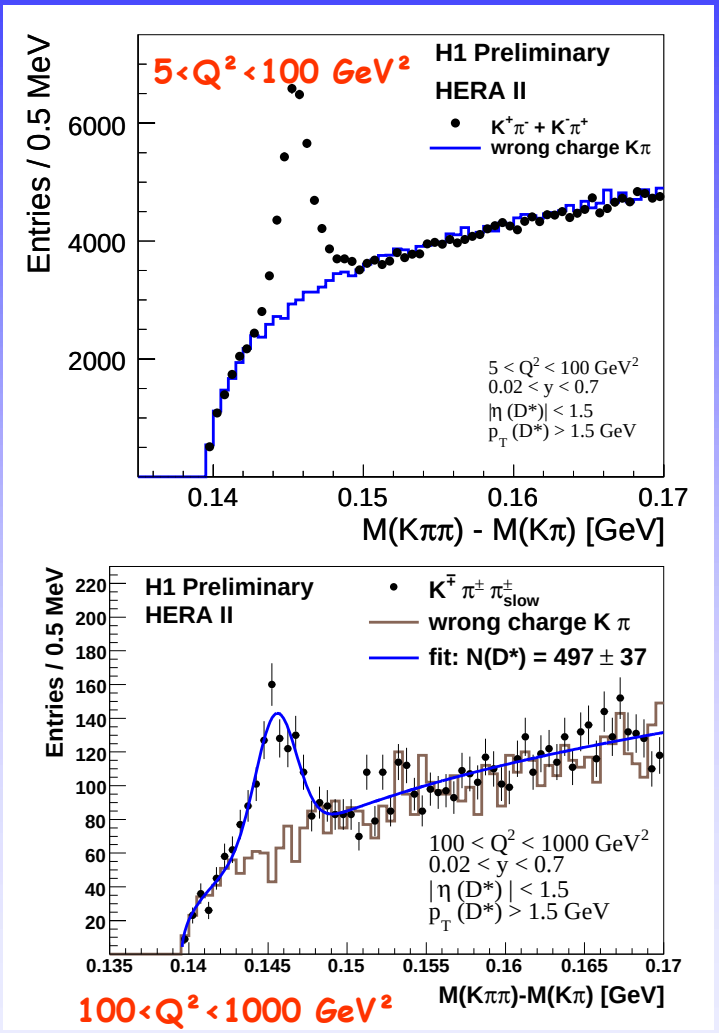
Reconstruction of D^{*+} mesons

- Golden decay mode:

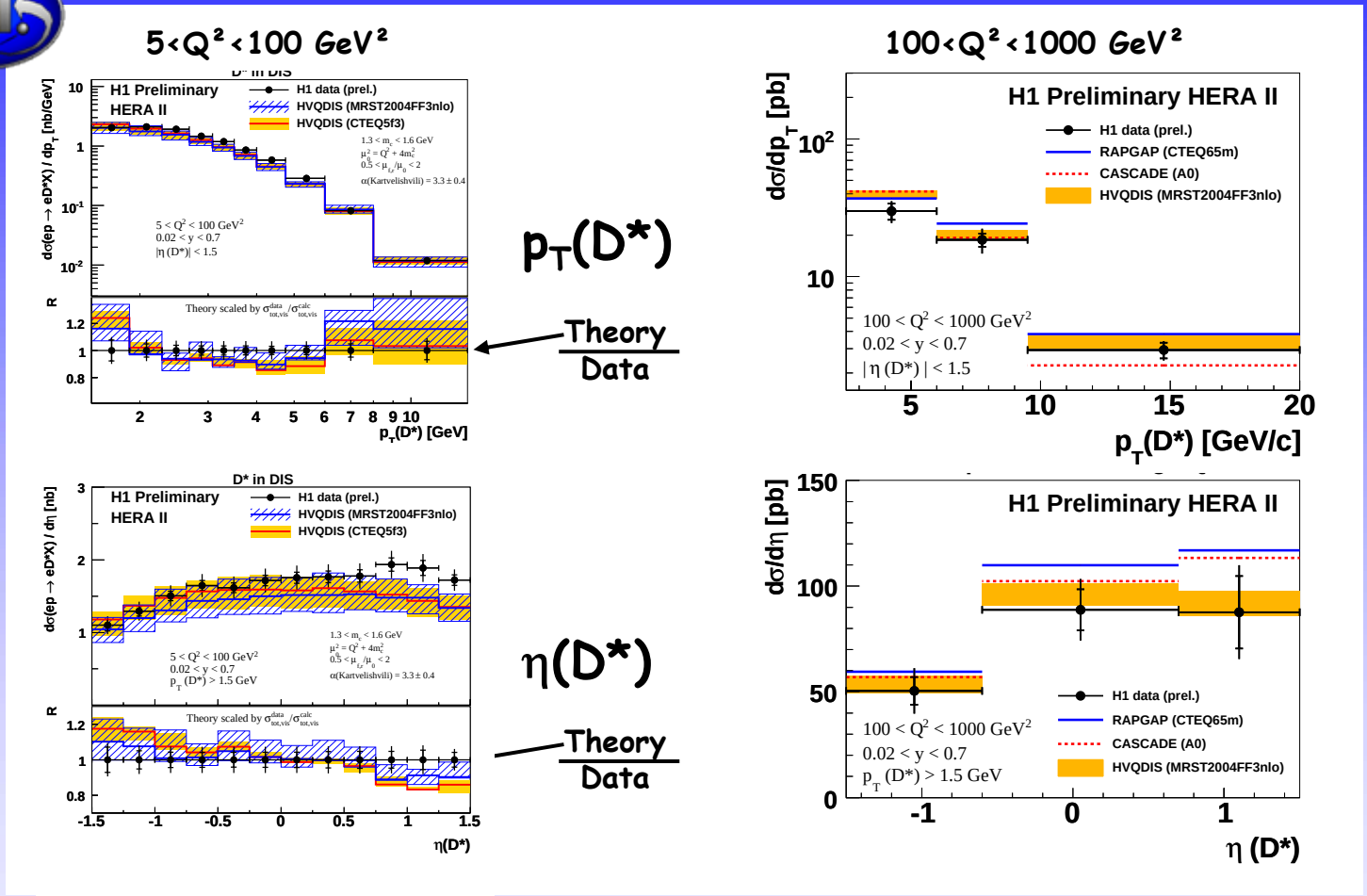
$$D^{*+} \rightarrow D^0 \pi^+_s \ (+c.c.)$$
$$\hookrightarrow K^- \pi^+$$

- Kinematic range:
$5 < Q^2 < 100\ GeV^2$ and
$100 < Q^2 < 1000\ GeV^2$
$0.02 < y < 0.7$
$P_t(D^*) > 1.5\ GeV$
$|\eta(D^*)| < 1.5$

- Data Sample
350 pb^{-1}
(2004-2007)

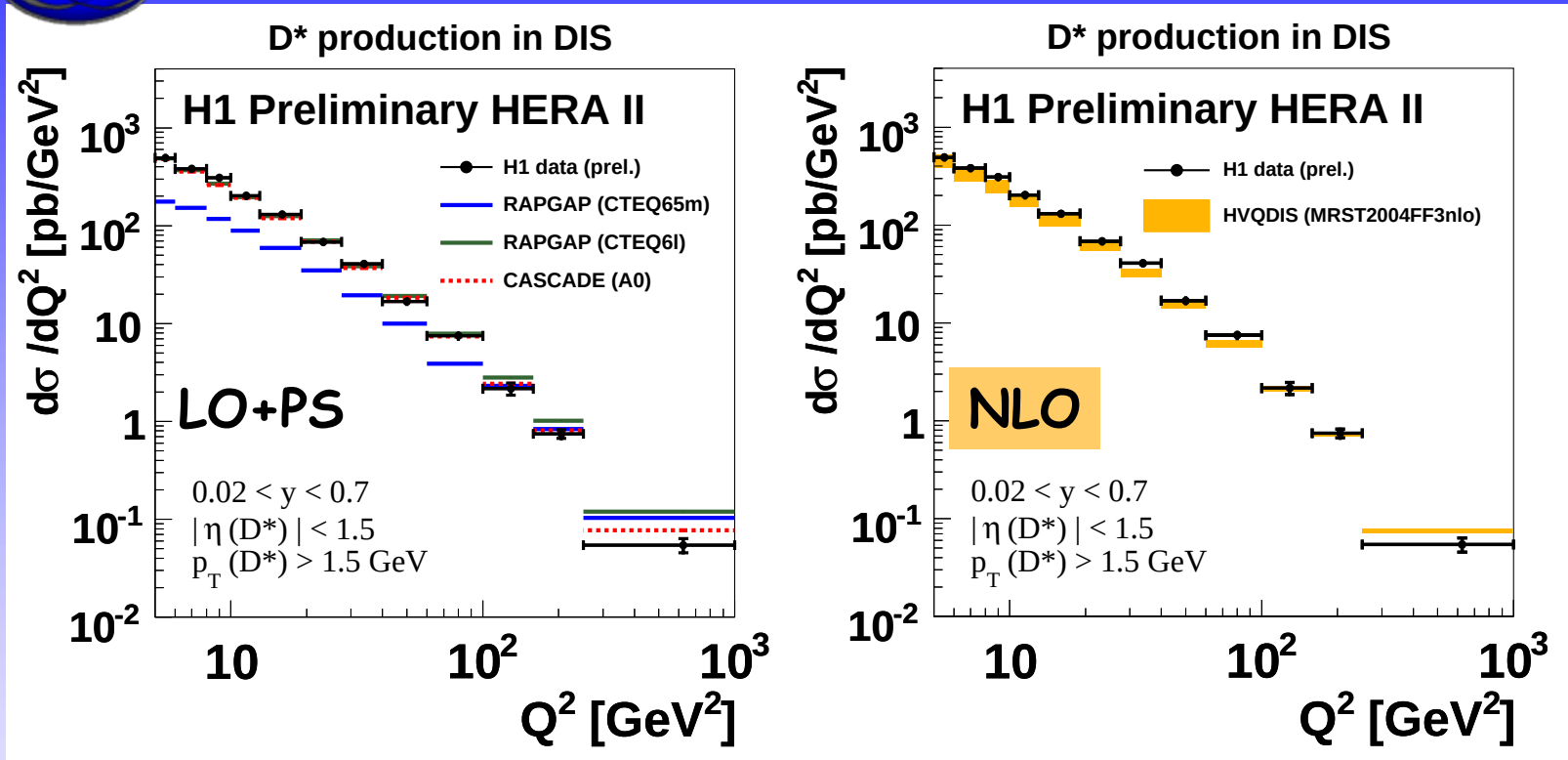


Inclusive D^{*+} cross sections - p_t, η



- Reasonably well described by NLO QCD
- different shapes in p_t and η for $Q^2<100$ GeV^2 for both PDF's

Inclusive D^{*+} cross sections - Q^2



- Reasonably well described by NLO QCD – albeit different shape
- RAPGAP fails to describe the data in full Q^2 range
- CASCADE yields a better description

Reconstruction of D^+ and D^0 mesons

- **Reconstructed decay modes:**

$$D^+ \to K^-\pi^+\pi^+ \text{ (+ c.c.)}$$
$$D^0 \to K^-\pi^+ \text{ (+ c.c.)}$$

(D^0 not from $D^{*+} \to D^0\pi^+$)

- **Decay products originate from reconstructed secondary vertex with significance**

$$S_{XY} = L_{XY}/\sigma(L_{XY}) > 3 \ (D^+)$$
$$> 1 \ (D^0)$$

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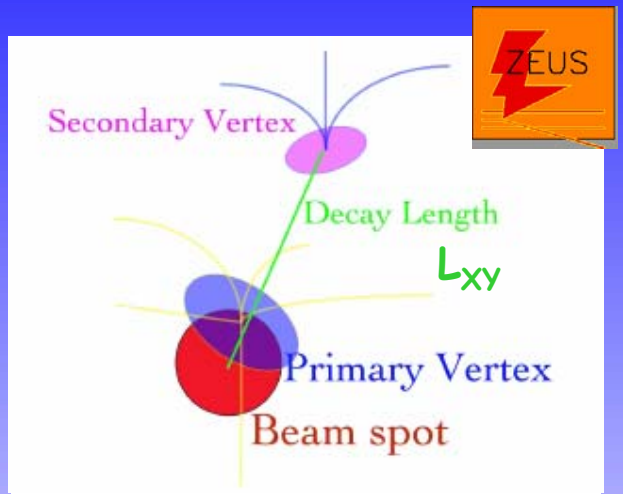
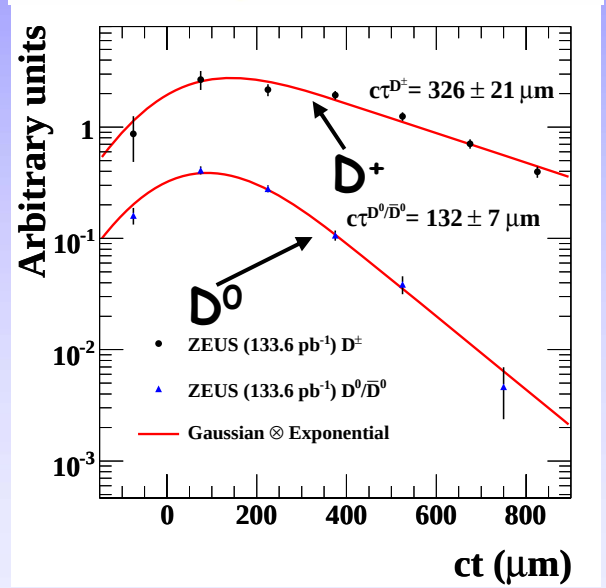




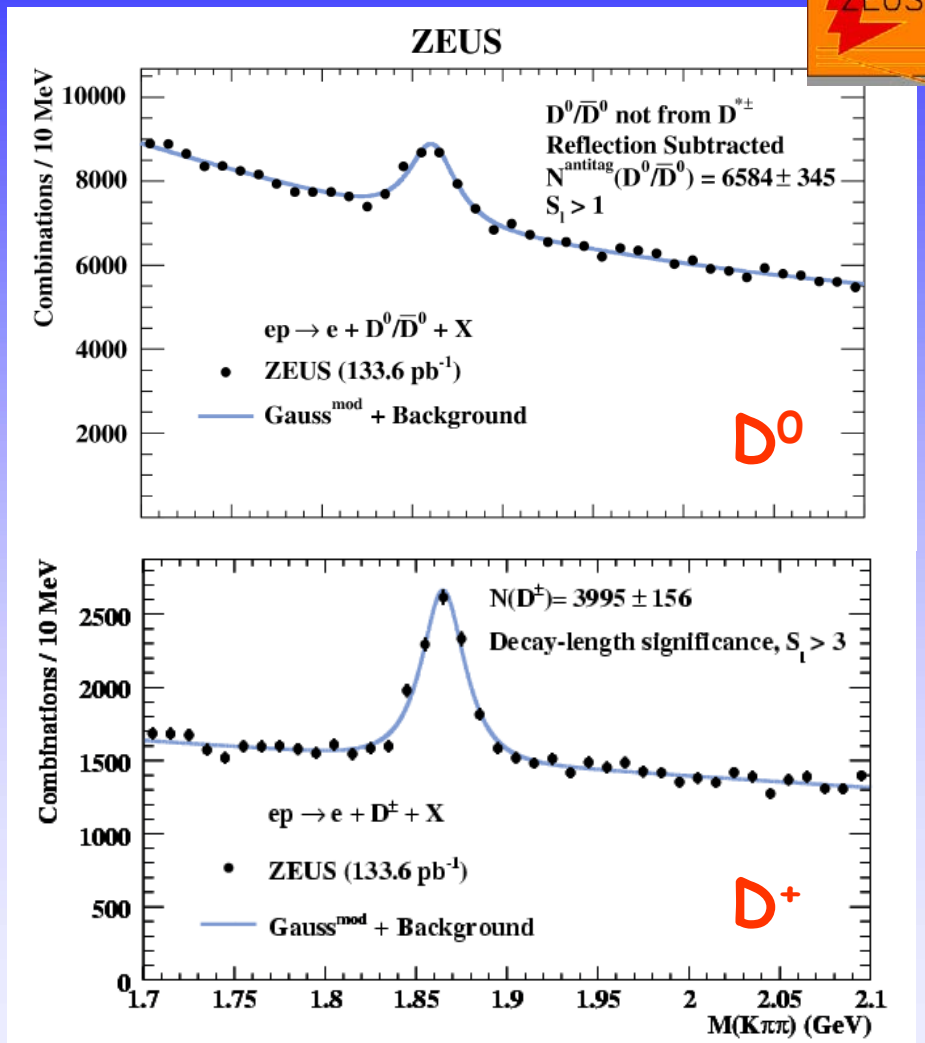
D^+ and D^0 mesons and selection

- **Kinematic range:**

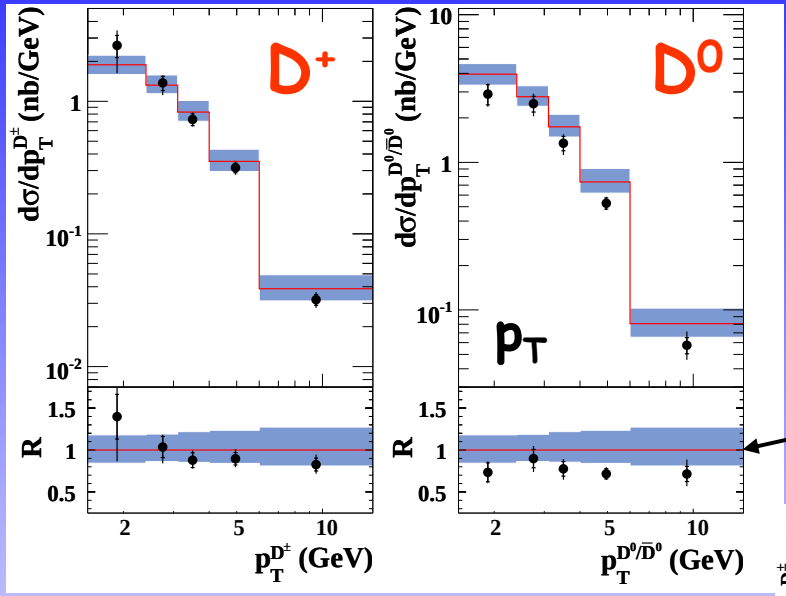
$5 < Q^2 < 1000\ GeV^2$
$0.02 < y < 0.7$

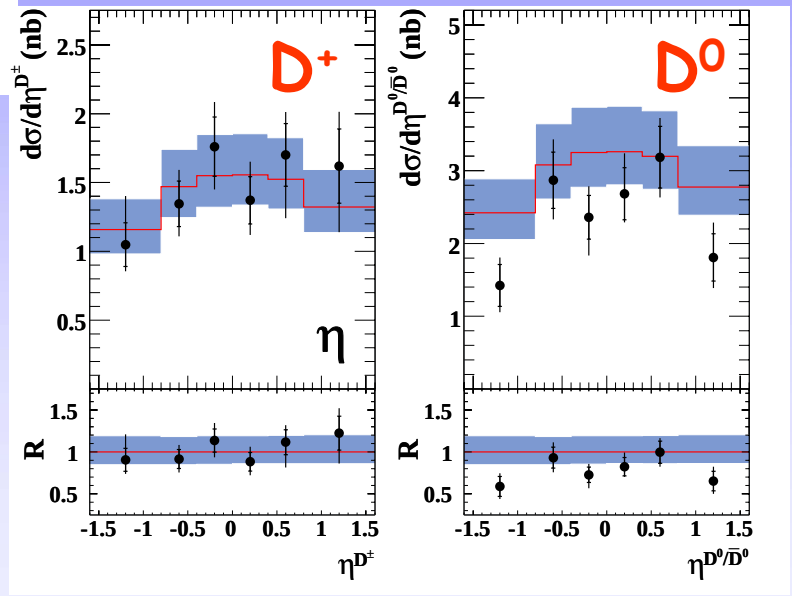
$1.5 < p_T(D) < 15\ GeV$
$|\eta(D)| < 1.6$

- **Data Sample:**
$133.6\ pb^{-1}$
(2004/05) e^-p



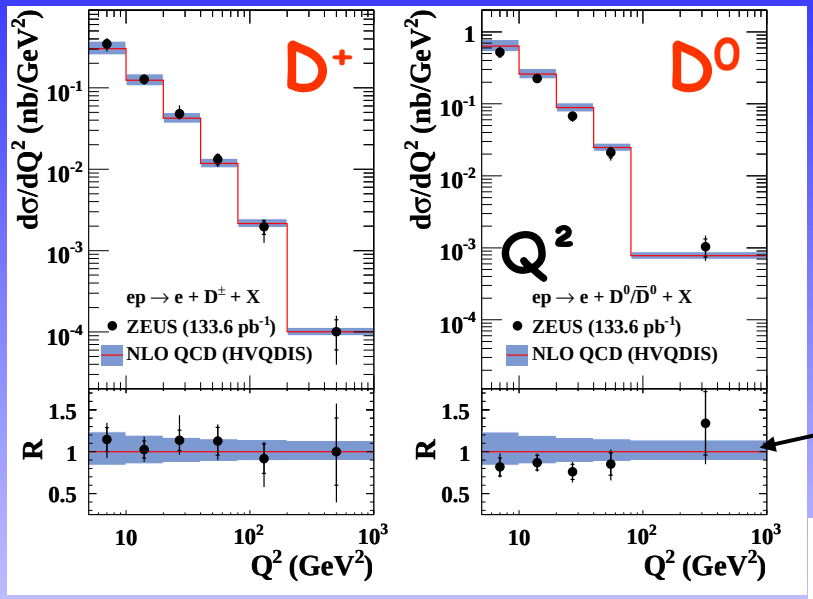
Inclusive D cross sections - p_T and η



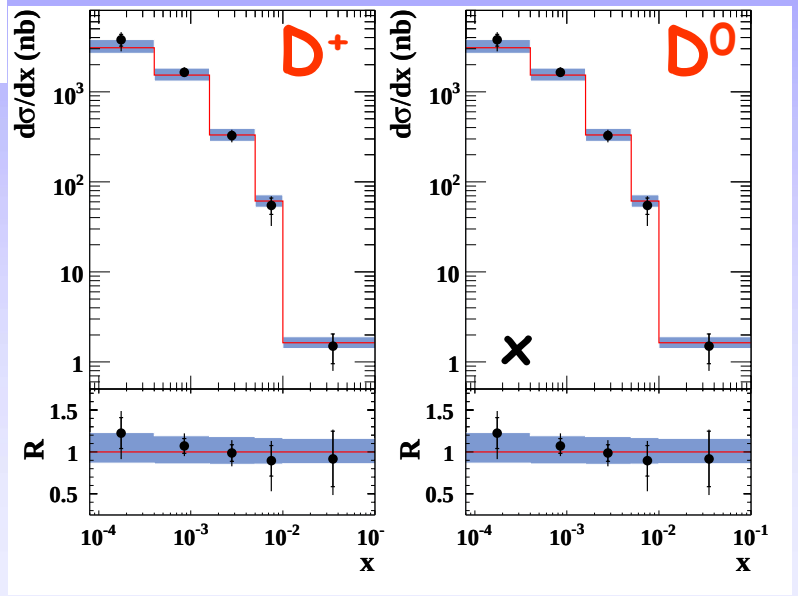


Good description of data by massive NLO QDC calculations HVQDIS

Inclusive D cross sections - Q^2 and x



Data / Theory



Good description of data by massive NLO QDC calculations HVQDIS

Charm contribution to the proton structure function

Charm structure function:

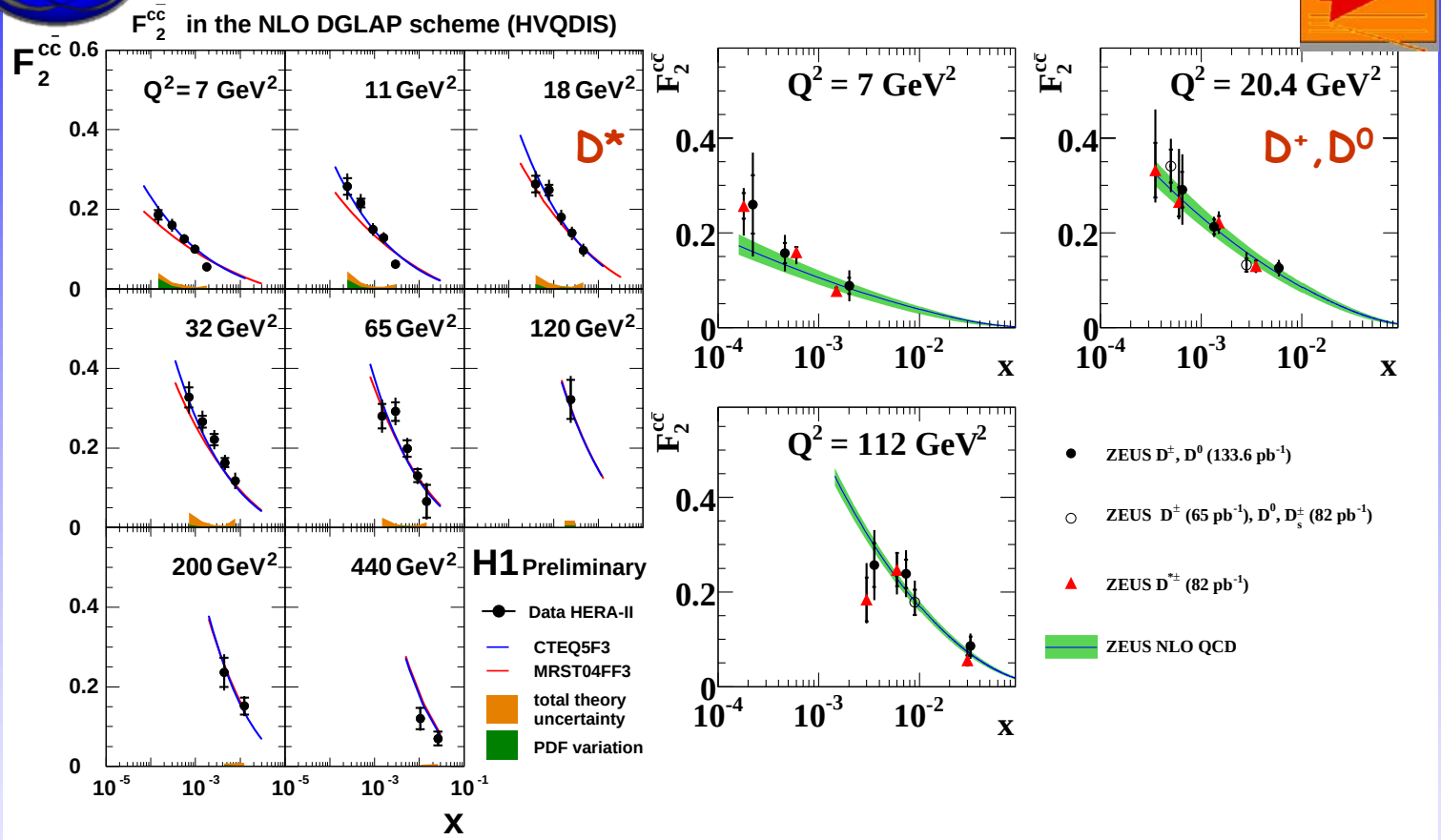
$$\frac{d^2\sigma}{dxdQ^2} = \frac{2\pi\alpha_{em}}{Q^4 x} \cdot \left(Y_+ F_2^{c\bar{c}} - \frac{y^2}{Y_+} F_L^{c\bar{c}} \right) \quad \text{with} \quad Y_+ = 1 + (1 - y^2)$$

visible inclusive D cross sections are converted to F_2^{cc} via

$$F_2^{c\bar{c}}(\exp) = \frac{\sigma_{vis}(\exp)}{\sigma_{vis}(theory)} F_2^{c\bar{c}}(theory)$$

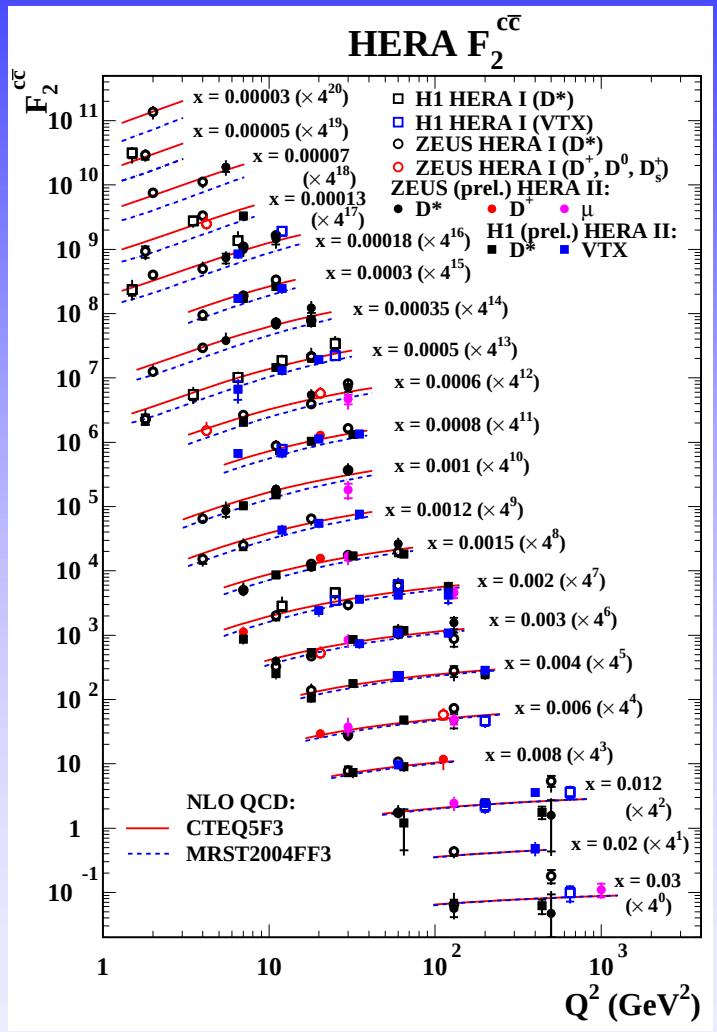
complication: visible range of detected D mesons covers only ≈ 30% of the phase space
⇒introduces model dependent extrapolation uncertainties (more details see next talk by K. Lipka)

F_2^{cc} from D mesons



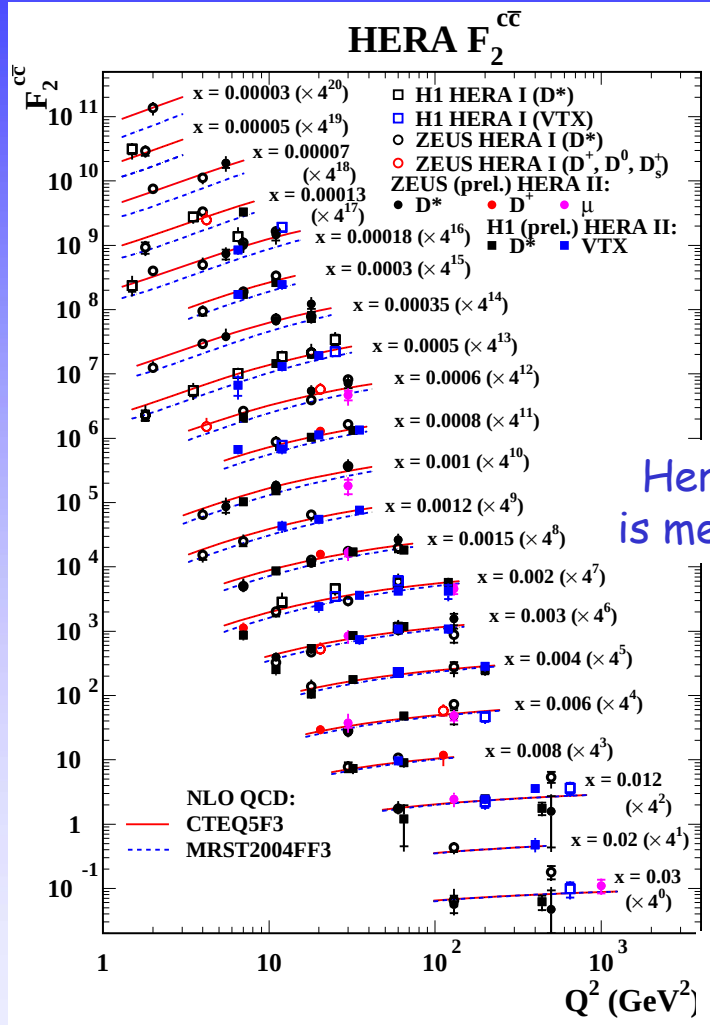
Massive NLO predictions with PDF's from global analyses or inclusive F_2 agree well with data

F_2^{cc} from HERA

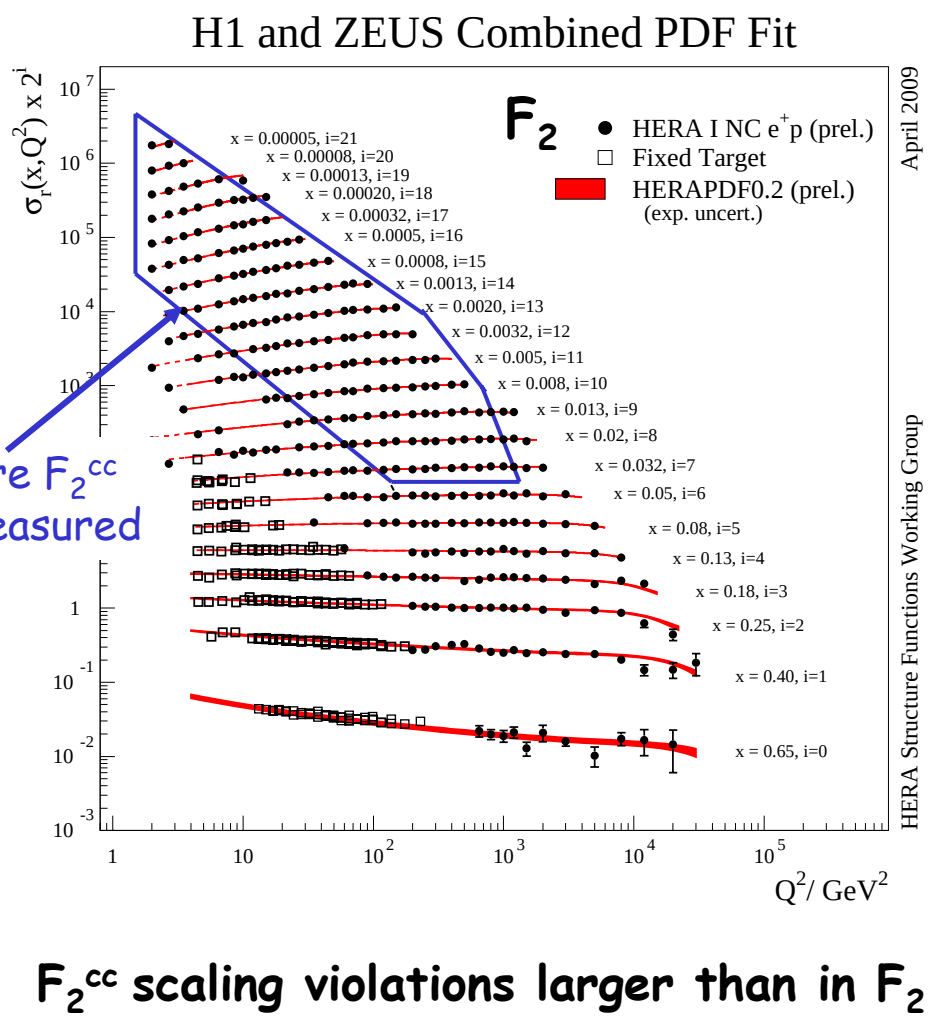


- Large scaling violations in F_2^{cc}
- Data sensitive to the gluon density in the proton

F_2^{cc} from HERA



Here F_2^{cc} is measured



F_2^{cc} scaling violations larger than in F_2

Conclusions

- New results on D meson production in DIS at HERA have been presented
- Inclusive visible cross sections are reasonably well described by
  - LO+PS Monte Carlo RAPGAP and CASCADE
  - massive NLO calculation HVQDIS
- Charm contribution F_2^{cc} to the proton structure function has been extracted
  - F_2^{cc} data cover a large part of the (x,Q^2) plane accessible by inclusive F_2 measurements
  - F_2^{cc} data will crosscheck the gluon density
  - Scaling violations in F_2^{cc} significantly larger than in F_2

Backup